

FINAL

STATUS REPORT: NAG2-860, NAG2-937

68537

submitted to the
National Aeronautics and Space Administration
by the
Laboratory for Astrophysics,
National Air and Space Museum, Smithsonian Institution

INFRARED CORONAL LINES OF ACTIVE GALACTIC NUCLEI

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JUL 31 1996
CASE

1. REVIEW OF THE PROPOSALS

Proposals were submitted in response to NRA2-35434 and NRA2-35971 for a KAO Guest Investigator observing program using HIFOGS. Grants NAG2-860, NAG2-937 were awarded to support FY94 observations for this program entitled “Infrared Coronal Lines of Seyfert Nuclei”. The main science objective was to obtain the first 5-9 μm spectra of the Seyfert galaxy NGC 1068 to search for infrared coronal lines that were predicted by Spinoglio & Malkan (1992, hereafter SM92), and Greenhouse et al. (1993). One flight from ARC on the program object NGC 1068 was scheduled during November 1994 and a working flight from ARC to HAFB Hawaii was scheduled during September 1995.

2. PROGRAM STATUS

Results and analysis from our Nov 94 flight (NAG2-860) were discussed in detail in §4 of our NAG2-937 proposal. The data returned from this flight were ambiguous. However, based on these Nov 94 results, we determined that a higher signal to noise ratio and higher line to continuum ratio spectrum could be achieved using a smaller than normal aperture to reduce sky noise and a higher than normal order of the grating to increase resolution. This plan was proposed and approved for a second flight during Sep 95.

This Sep 95 observation (the last flight of HIFOGS) was completely successful and resulted in discovery of two new coronal lines in NGC 1068 ([Ne VI] and [Mg V]) in addition to a low ionization species [Ar II] (see Figure 1). The argon line, observed for the first time in this galaxy, was found to exceed the model prediction for NGC 1068 (SM92) by more than two orders of magnitude. The [Ne VI] line was found to be a factor of 20 brighter than predicted by SM92. These new data show that the coronal line emitting region (CLR) of NGC 1068 can not be modeled as a single zone photoionized region (Figure 2) and will allow a neon abundance to be determined for the CLR. These [Ar II] data also show that photodissociation regions occupy an unexpectedly large volume filling factor within the 1 Kpc diameter region observed by the KAO.

The results of our Sep 95 flight were combined with complementary ground-based data obtained as part of this program using the Palomar 5 m (Table 1) and were presented at the International Astronomical Union Meeting 159 “Emission Lines In Active Galactic Nuclei” held in Shanghai China during June 1996. They will be published in those proceedings. Grant NAG2-937 is currently under extension while final modeling and analysis are completed and a

manuscript reporting these results is prepared for the Astrophysical Journal. These remaining analysis and publication costs are being borne by NAG2-937. Activities under NAG2-860 are completed.

3. REFERENCES

Greenhouse et al. 1993, ApJS, 88, 23.

Spinoglio, L. & Malkan, M.A. 1992, ApJ, 318, 370.

4. FIGURE CAPTIONS

Figure 1 – The 5-8 micron spectrum of NGC 1068 obtained using the faint object spectrograph (HIFOGS) on the Kuiper Airborne Observatory (KAO) using a 13 arc-second diaphragm. The spectrum shown is a statistically weighted average of 5-7 measurements taken with two grating positions to achieve Nyquist sampling of the detector array. The uncertainty in the integrated line flux is shown with the line identifications. Spectral resolution, measured wavelengths, and other details are listed in Table 1.

Figure 2 – CLOUDY modeling of the NGC 1068 coronal line region is shown by solid squares. We find that the best fit model is: power law spectral index = -1.75, cutoff = 50 and 10^{-3} Ryd, column density = 10^{23} cm $^{-2}$, $n_e = 10^3$ cm $^{-3}$. The measured data are shown by circles. The length of the reddening vector corresponds to 10 magnitudes of foreground extinction. The left panel illustrates the need for an additional ionization component other than the AGN radiation field to increase the abundance of Si $^{+5}$.

TABLE 1

NGC 1068

Line	$\lambda_{\text{calculated}}$	$\lambda_{\text{observed}}$	$(\delta\lambda)_{\text{instrument}}$ (km/s)	Linewidth (km/s)	F_{observed} (10^{-13} erg s $^{-1}$ cm $^{-2}$)	$F_{\text{observed}}/F_{\text{SM92}}^2$
[ArIII]	8.991	8.985	137	624	18	3.23
[SIV]	10.541	10.507	114	854	49	1.16
[NeII]	12.813	12.804	91	577	28	3.94
[ArII]	6.985	6.972	...	...	154	142.6
[SiX] ¹	1.430	...	...	...	2.7 ± 0.5	7.30
[Si VII] ¹	2.481	...	...	1000 ³	8.3 ± 0.9	1.18
[Si VI] ¹	1.964	...	...	1000 ³	8.0 ± 0.5	1.29
[Ne VI]	7.642	7.676	540	...	357	18.9
[Mg V]	5.608	5.566	540	...	122	3.91

¹Thompson 1996²Predicted values from Spinoglio and Malkan, 1992.³Moorwood 1991

NGC 4151

Line	$\lambda_{\text{calculated}}$	$\lambda_{\text{observed}}$	$(\delta\lambda)_{\text{instrument}}$ (km/s)	Linewidth (km/s)	F_{observed} (10^{-13} erg s $^{-1}$ cm $^{-2}$)	F_{SM92} (10^{-13} erg s $^{-1}$ cm $^{-2}$) ¹
[ArIII]	8.991	8.980	137	< 298	3.1	1.3
[SIV]	10.541	10.500	114	362	5.0	7.1
[NeII]	12.813	12.803	91	310	11.7	3.6

NGC 5506

Line	$\lambda_{\text{calculated}}$	$\lambda_{\text{observed}}$	$(\delta\lambda)_{\text{instrument}}$ (km/s)	Linewidth ⁴ (km/s)	F_{observed} (10^{-13} erg s $^{-1}$ cm $^{-2}$)
[ArIII]	8.991	8.995	137	< 273	6.9
[SIV]	10.541	10.515	114	214	7.2

⁴Narrow component

Figure 1

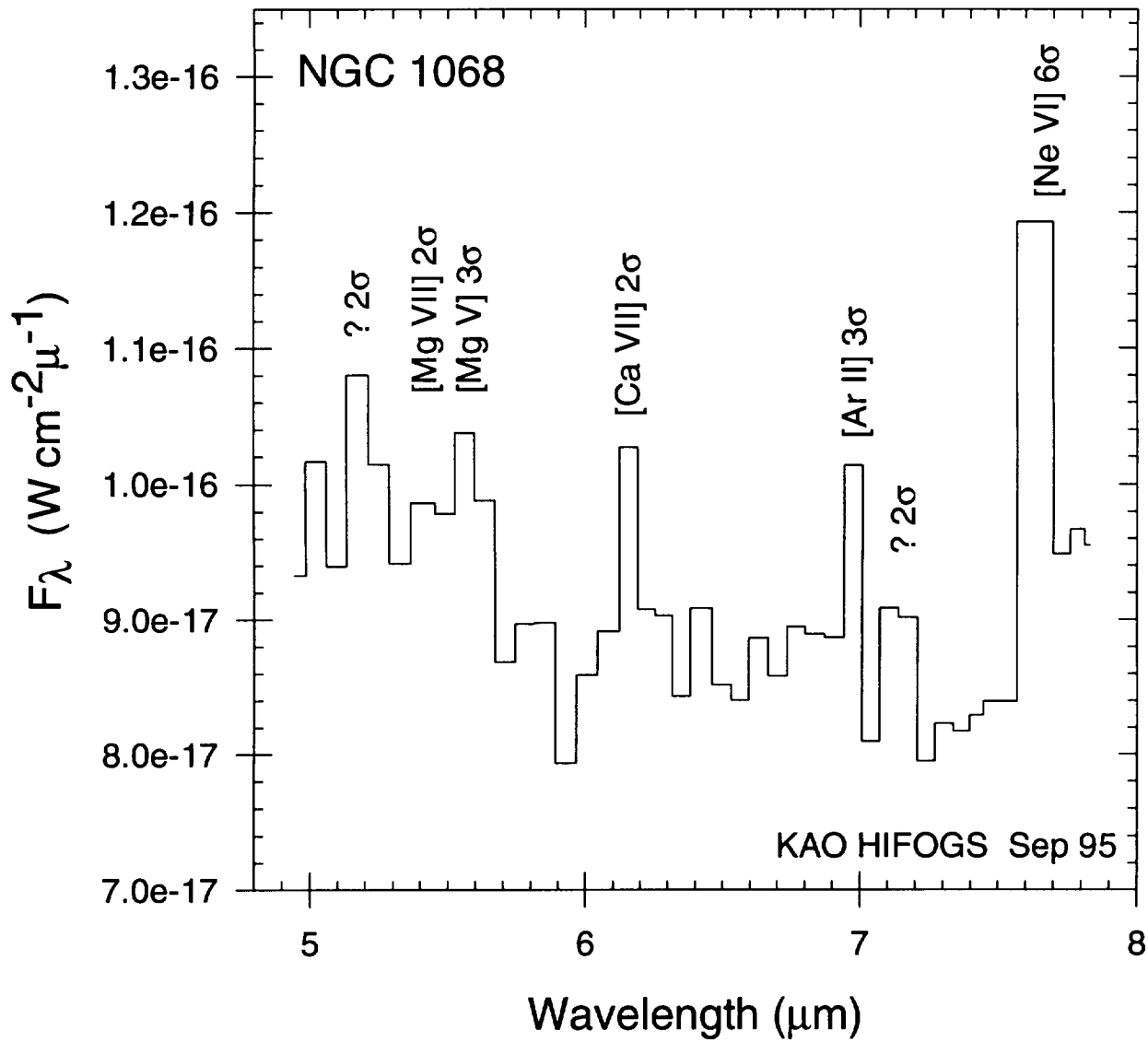


Fig 2

